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Sauk River flowing through a mature forest of Douglas fir (*Pseudotsuga taxifolia*). Snoqualmie National Forest, Washington. (See "The Establishment of a Douglas Fir Forest.")

THE ESTABLISHMENT OF A DOUGLAS FIR FOREST[1]

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Douglas fir (*Pseudotsuga taxifolia*) has gained and held possession of by far the greater part of the forested area of the Cascade and Coast region of Washington and Oregon. The dominant position of this tree in the plant formations of the region has not been attained through any one characteristic, but rather through ability to overcome many varying and extreme conditions through a grouping and regrouping of a number of characters. This varied combination of characteristics gives Douglas fir a wide range of adaptation and a resultant superiority over its associates.

The seed of Douglas fir is peculiarly sinted for regeneration, and in favorable seed years which occur at irregular periods, is produced in large quantities. When the seed crop is light the seeds are generally attacked by an insect (*Megastigmus spermotrophus* Wachtl) which destroys before maturity a large percent of the few seeds which would otherwise be produced. Heavy seed crops are advantageous, because the seeds of this species are the favorite food of rodents. This paradox is explained by the fact that, with a heavy crop, the surplus produced over the amount consumed by rodents is large, and is stored away by the rodents in the duff and mineral soil of the forest floor, in caches varying in size from a few seeds to bushels of cones. These caches are not used in the fall, and before the following spring all traces of the rodents' work have been eliminated by the snow and rain. The seeds are thus preserved in their natural storage of cool temperature and moisture conditions which reduce the oxygen content of the soil. How long the seed will remain viable in this natural storage is not known. Experimental evidence has proved it to be viable after six years, but it may lie an indefinitely longer period. These conditions demonstrate the biological relations of the forest which must not be overlooked in the study or control of either the flora or fauna of a region.

In the forest, seeds which remain near the surface and receive favorable germinating temperatures will germinate, but the seedlings do not become established. The Douglas fir is not a shade enduring species, especially in cool situations. Consequently, it has very little chance to reproduce under a forest canopy. This character eliminates it as an under story, and is the underlying factor which makes the Douglas fir a one-generation tree in the

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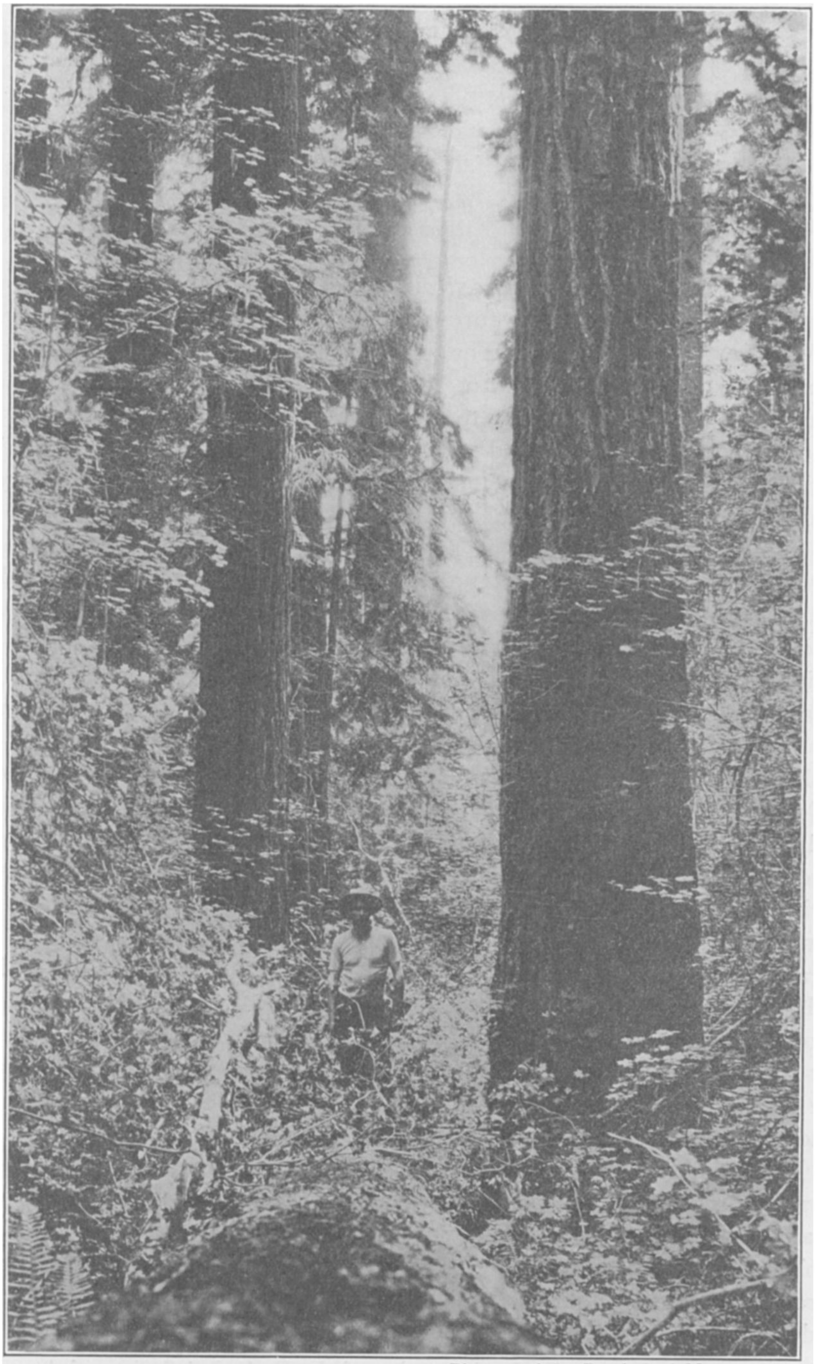
[1] Presented before the St. Louis meeting of the Ecological Society of America in December, 1919. Published by permission of the Secretary of Agriculture.



Photograph by Barrington Moore, 1913.

FIG. 1. A typical forest of Douglas fir (*Pseudotsuga taxifolia*) more than 200 years old but still thrifty. Picture taken from top of a log four feet in diameter owing to undergrowth of vine maple. Winberry Creek, Cascade National Forest, Oregon.

natural cycle of this formation. In the establishment of a sere the Douglas fir appears through only one generation, while its associates, the western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) may be represented by several generations during the stages of succession, and be reproduced indefinitely after the *Thuja-Tsuga-hylium,* which is the climax forest, is established. This condition is brought about by the shade-enduring characters of the cedar and hemlock during all stages of their development.

With such a large percent of the extensive cedar-hemlock climax forest occupied by a Douglas fir formation, the significance of factors other than competition is emphasized. The Douglas fir formation (*Pseudotsuga-hylium*) is not, as might appear, a retrogression from the cedar-hemlock climax, but is rather the stage of succession preceding the climax.

The principal combination of factors responsible for the preponderance of the Douglas fir formation is the presence of seed stored in the forest floor, and of fire. When the forest is removed by fire, or by cutting, the stored seed is left under favorable germination conditions and immediately responds to the stimuli. The result is an immediate replacement by the species which occupied the ground before the fire. The proportions of the species in the young growth may vary from the proportions of the previous mature forest. An important factor in this variation of proportion of species is the amount of seed cached by the rodents. Larger amounts of Douglas fir seed are cached than of hemlock or cedar, which gives this species an advantage after the forest is removed. The same holds true of the western white pine (*Pinus monticola*).

The seeds of the white pine are relished by rodents and are greedily gathered and stored. So pronounced is this influence that often Douglas fir and western white pine make up as much as 75 percent of the young growth where the mature stand contained only 2 percent of these species. The removal of a forest results in changed conditions of soil moisture and temperature and local changes in atmospheric conditions. These changes often produce a xerophytic site where a mesophytic site prevailed while the area was forested. The drying out of sites is also a favorable factor in assisting the Douglas fir to conquer its associated species. The Douglas fir seed germinates quickly under favorable conditions, and the seedling produces a long radicle during its early stages of growth. This is so pronounced compared with hemlock and cedar that it enables the Douglas fir to become established where the others fail.

On dry sites, such as the large Cispus burn of 1918, northwest of Mt. Adams, where nearly 150 square miles of forest were burned over, the ability of establishment often determines the species of the forest during the first stages of succession. The ability of the Douglas fir to develop a root system 6 to 8 inches deep during the early part of its first growing season is an important factor in retaining the Douglas fir formation.

This is proved by the soil moisture readings and the wilting coefficient of Douglas fir seedlings. On the south slope the surface soil moisture reached a minimum of .18 percent in July and did not go above .85 percent in August, while at a depth of 6 inches the south slope soil contained 6.55 percent moisture in July and 5.50 percent in August. The wilting coefficient of 2-year-old Douglas fir seedlings was found to be 1.25 percent for this soil.[2]

It is obvious from these data that seedlings could not germinate or live in the surface layer of soil, since the moisture content was below the requirement of the seedlings. At a depth of 6 inches, however, there was sufficient moisture for growth all through the season. Consequently, any seedlings with roots penetrating to the 6-inch depth would become established.

The soil is mostly a volcanic ash, very loose and porous, and is underlaid with rock or clay at depth of 2 to 6 feet on the slopes.

On the flat river valleys the soil contains a silt loam which lowers the wilting coefficient but does not retain sufficient moisture in the surface soil to secure germination or establishment. The surface soil contained .19 percent of moisture in July and 09 percent in August, and the wilting coefficient of Douglas fir 2-year-old seedlings was found to be .94 percent for this soil. At 6 inches the soil contained 11.45 percent of moisture in July and 9.32 percent in August. Obviously, then, seedlings must have root systems which penetrate to a six inch depth before July in order to become established in this region. These conditions of moisture confine the shallow-rooted seedlings of hemlock and cedar to the most favorable slopes and the moist draws.

The extreme soil moisture conditions are readily explained by the soil temperature and evaporation.[3] The soil on the south slope reached a maximum of 128° F. in July and 135° F. in August. The evaporation on the south slope from July 15 to October 1 was 1,070 cc. as compared with 690 cc. on the flat, that is, more than one and one half times as much on the flat. With such extreme temperature and moisture demands only those Douglas fir seedlings which are protected by shrubs or annuals survive the first one or two dry seasons and become established.

After a forest canopy is formed and duff accumulates on the surface, the site becomes more mesophytic, and cedar and hemlock are again able gradually to encroach on the Douglas fir forest. In this way the cedar and hemlock under story is established, permitting the Douglas fir to be the dominant tree only during the first generation except in the localities which cedar or hemlock do not reach by migration until two or more generations of Douglas fir have occupied the ground.

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[2] [It would be interesting to know if the wilting coefficient of Douglas fir differs from that of wheat. Briggs and Shantz evidence of the similarity of the wilting coefficient of different plants (U. S. Dept. Agr. Bu. of Plant Industry, Bul. 130, 1912) has never, so far as we know, been experimentally disproven.—EDITOR.]

[3] Evaporation records were taken with the Bates' Type 4 Evaporimeter.

SUMMARY

The measurable characteristics of the Douglas fir, which give it such a prominent place in a formation of which cedar and hemlock comprise the climax forest, may be briefly stated: The production of heavy crops of seed which is the favorite food of the indigenous rodents; caching of seed by rodents in the forest floor; ability of the seed to retain its viability while stored in the forest floor and to live through forest fires; early and quick germination of the seed under favorable conditions; and a rapid development of a long radical.

The unfavorable factors are the inability of the Douglas fir to withstand shade, which results in its elimination from the under story of the forest and consequent elimination from the climax forest.

These factors are within the control of man, and it is on them that the scientific management of Douglas fir must be based in order to keep the Pacific Northwest region under continuous natural production of this most important species.

[*Note.*—Are the rodents protected in Washington and Oregon, or are they being exterminated? The proper handling of rodents becomes of great importance in reproducing the Douglas fir, and is a subject for cooperation between foresters and zoologists. Reproduction of western yellow pine (*Pinus ponderosa*) from seed stored by rodents has been noticed by the editor on the east slope of the Cascade Mountains in Oregon. What other forests show reproduction by the same agency? EDITOR.]